Structural Vibration Signature Modeling

This NASA developed software incorporates first principles modeling capabilities to simulate normal and damage structural vibration signatures, especially in rotating systems. It represents an indispensable test bed that will support a broad spectrum of structural health diagnosis and prognosis capabilities in the Exploration Vision.

Background

This first-principles modeling software is based on three revolutionary NASA advances:

1. A new algorithm for automated elliptic grid generation of generalized curvilinear grids about any arbitrary geometry (U.S. patent application has been filed for the algorithm),

2. Finite-difference solution of three-dimensional elastodynamic equations in generalized curvilinear coordinates over this computational grid, and

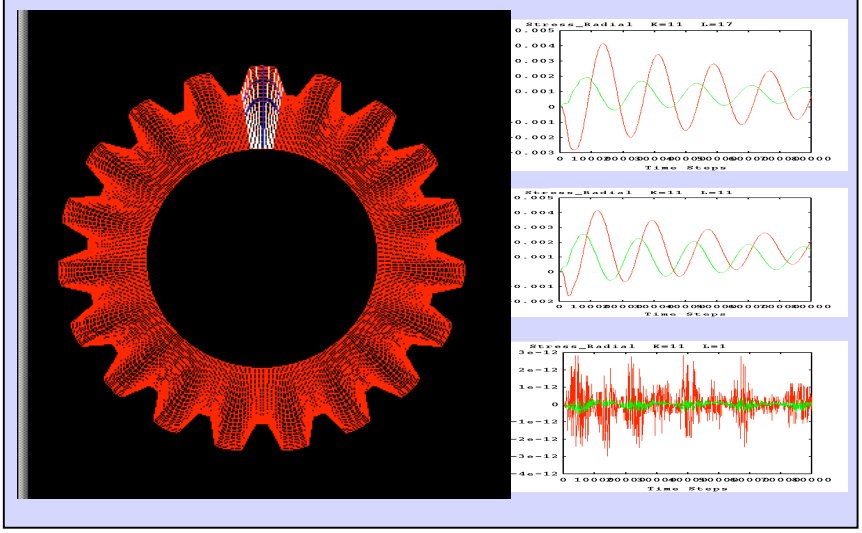
3. An interactive visual simulation environment based on OpenGL, where one can start a simulation, suspend it at anytime to inspect intermediate results, and resume or stop the simulation.

Model validation results for an annulus and a thin disk are shown here. Preliminary results show the case of a two-dimensional gear that is impulsively rotated at 100 rps from an initial state of rest. The impulsive rotation throws the gear in a state of damped vibration about the steady state configuration that would be attained by the gear if it were set into rotational motion gradually. Also shown are damage vibration signatures at three different locations corresponding to a fault seeded in one of the gear teeth. The objective here is to model the gear pair dynamics in mesh, as shown overleaf.

Research Overview

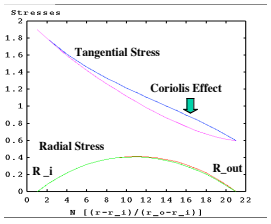
First-principles modeling research was motivated by the need to define a reference vibration signature space. As initially anticipated, this is now serving as a unique test bed for calibration and validation of structural fault-detection algorithms in a wide variety of engineering systems, especially rotating machinery. Indeed, engineering systems such as these will also be used to accomplish NASA's Exploration Vision.

Damped Vibrations - Radial Stress Time Evolution at Selected Locations
Gear Impulsively Rotated at 100 RPS
Comparison Between Normal and Fault Data

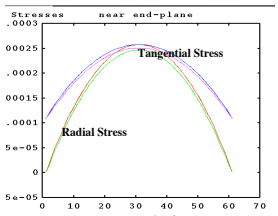


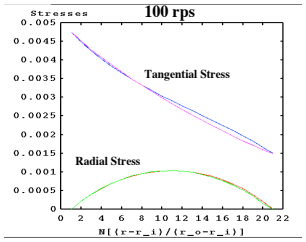
STRUCTURAL DYNAMICS SIMULATOR VALIDATION -
comparison between theory and computations

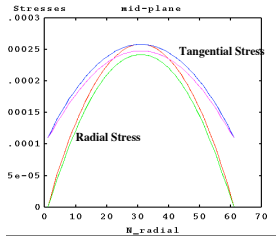
Disk with Hole (2-D) - Axisymmetric Radial and Tangential Stress Distributions
2000 rps



Thin Solid Disk (3-D) - Axisymmetric Radial and Tangential Stress Distributions - 100 rps







Structural Vibration Signature Modeling

In order to develop valid fault-detection algorithms, the present first-principles modeling capability will serve as a key element in the diagnosis and prognosis development infrastructure for ISHM.

Recent Technical References

Kaul, U. K., “Enhanced Elliptic Grid Generation," Patent application filed with the U.S. Patent and Trademark Office on Nov. 11, 2003,NASA Case No.: ARC-14710-1

Kaul, U. K., “New Boundary Constraints for Elliptic Systems Used in Grid Generation Problems,” *Journal of Computational Physics*, vol 189/2, pp 476-492,, 2003

Kaul, U. K. and Huff, E. M., “Elliptic grid generation of spiral-bevel pinion gear typical of OH-58 helicopter transmission, NASA TM-2002-210932, February 2002

Kaul, U. K. and Huff, E. M., “Automated gear teeth grid generation via solution of elliptic pdes,” SIAM Conference on Geometric Design and Computing, Sacramento, CA., Nov. 5-8, 2001

Hambaba, A., Huff, E. M.. and Kaul, U. K., “Detection and Diagnosis of Changes in the Time-Scale Eigenstructure for Vibrating Systems,” Proc. 2001 IEEE Aerospace Conference Proceedings, Big Sky, MT, March 10-17, 2001, ISBN: 0-7803-6599-2, Product No.: TH8542-TBR

Hambaba, A., Huff, E. M.. and Kaul, U. K., “Time-Scale Local Approach for Vibration Monitoring,” Proc. 2001 IEEE Aerospace Conference Proceedings, Big Sky, MT, March 10-17, 2001, ISBN: 0-7803-6599-2, Product No.: TH8542-TBR

Relevance to Exploration Systems

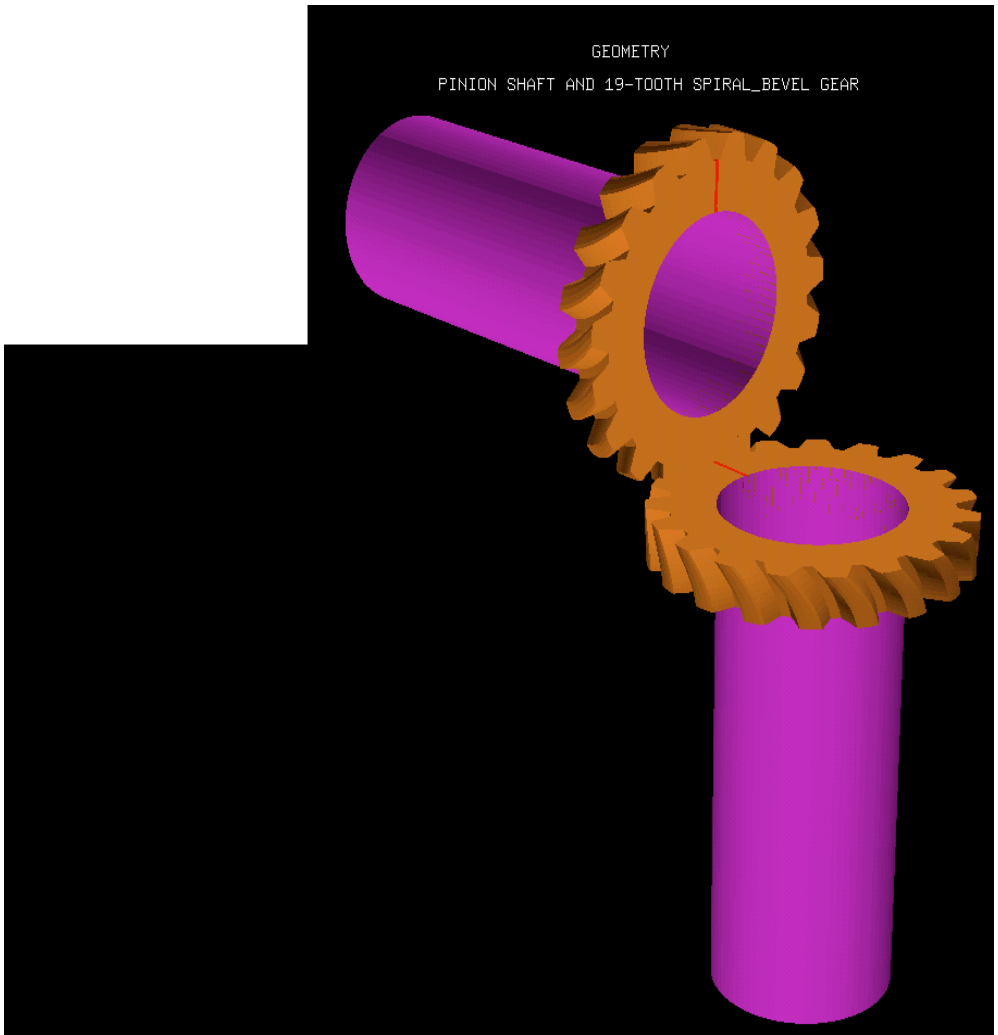
This research capability supports the following H&RT program /elements:

Software, Intelligent Systems, and Modeling

Points of Contact:

Dr. Upender K. Kaul
(650) 604-2973; ukaul@mail.arc.nasa.gov

Dr. Edward M. Huff
(650) 604-4870; ehuff@mail.arc.nasa.gov



Ames Research Center

NASA